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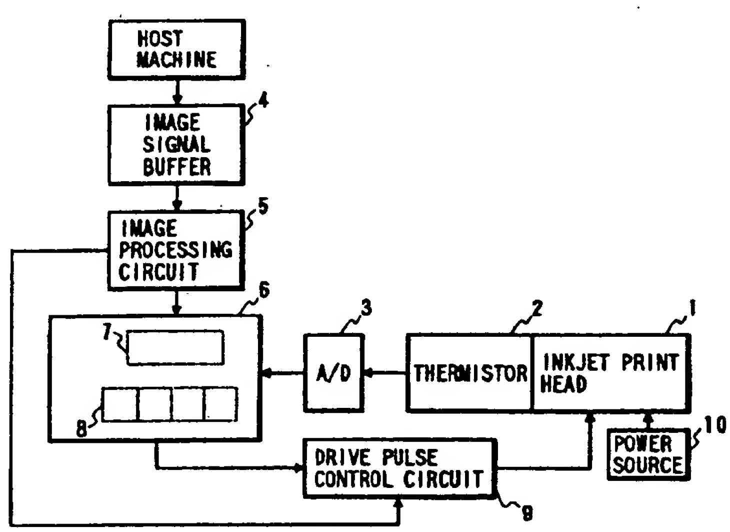
(54) Ink jet printing apparatus, a driving device for driving the ink jet printing apparatus, and an ink jet printing method

(57) An image signal, outputted from a host machine, is temporarily stored in an image signal buffer, and converted into bit signals for the heat generating resistors in an image processing circuit. Temperature information is derived from a thermistor attached to a ink jet print head, and converted into a digital signal by an A/D converter, and the digital signal is sent to a processor. The processor determines a correction level on the basis of the location of a block and the number of concurrent drives while referring to a correction-level determining table. The processor then determines a drive pulse condition on the basis of the correction level and a temperature of the ink jet print head while referring to a look-up tables. A drive pulse control circuit prepares a drive pulse signal on the basis of the bit signals of one line and the drive pulse condition, and drives the ink jet print head.

FIG. 1



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Description

BACKGROUND OF THE INVENTION

The present invention relates to an ink jet printing apparatus for ejecting ink droplets to a recording medium through nozzles by a pressure of bubbles to be generated to print an image on the recording medium, a driving device for driving the ink jet printing apparatus and an ink jet printing method.

The ink jet printing system has many advantages: - 1) High speed printing is possible. 2) Little noise is generated during the printing operation. 3) Images can be directly printed on normal papers. 4) No fixing process is required. 5) Size reduction of the apparatus is possible. Because of those advantages, the market accepts a gradual increase of using the ink jet printing system.

The ink jet printing system comes in two categories. In the ink jet printing system of the first category, an electro-mechanical transforming element is used for the means for ejecting. According to an input signal, it is mechanically deformed to eject an ink droplet to the recording medium through the nozzle. In the ink jet printing system of the second category, called a thermal ink jet printing system, an electro-thermal transforming element, i.e., a heat generating resistor element, is used for the jetting means. The resistor element receives a voltage pulse image signal to heat ink and to form bubbles thereon. By pressure caused by the bubbles, ink are ejected in the form of ink droplet through the nozzle.

Figs. 2A to 2C are sectional view showing a construction of a conventional ink jet print head. Fig. 2A is a cross sectional view showing a part of the print head when it is transversely cut at a right angle to the axis of a channel groove. Fig. 2B is a sectional view taken on line B - B' in Fig. 2A. Fig. 2C is a front view showing a part of the print head when viewed from the nozzle side. In the figure, reference numeral 21 designates a channel substrate; 22, a heat generating resistor substrate; 23, a channel groove; 24, a common liquid chamber; 25, nozzles; 26, a nonetching part; 27, a heat generating resistor; 28, an insulating layer; 29, a thick-film insulating or resin layer; 30, a first recess; 31, a second recess; 32, partitioning walls; 33, an ink droplet; and 34, an ink supply port. In Fig. 2, the thermal ink jet head, disclosed in Japanese Patent Laid-Open Publication No. Hei. 5-155020, is illustrated by way of example.

The channel groove 23 and the common liquid chamber 24 are formed on the channel substrate 21 by an anisotropic etching method. The opening of the channel groove 23 serves as the nozzle 25. The common liquid chamber 24 passes through the channel substrate 21. The opened top of the common liquid chamber 24 serves as the ink supply port 34. The heat generating resistors 27 and electrodes, not shown, for applying drive pulse signals to the heat generating resistors 27 are formed in the heat generating resistor substrate 22. The insulating layer 28 and the thick-film insulating layer 29 are further formed on and above the heat generating resistor substrate 22. The insulating layer 28 and the thick-film insulating layer 29 are partially removed from the heat generating resistor 27, to form the first recesses 30 therein. The second recess 31 for communicating the channel groove 23 with the common liquid chamber 24 is formed in the thick-film insulating layer 29. The channel substrate 21 is joined with the heat generating resistor substrate 22, and separated into individual head chips of ink jet print heads.

Through the ink supply port 34, ink is introduced into the common liquid chamber 24, passes through the second recess 31 defined by the thick-film insulating layer, and reaches the channel groove 23 as an ink fluid path. In the groove, the ink is heated by the heat generating resistor 27 and bubbles of ink are formed at the first recess 30 as the result of heating the ink. The ink bubbles presses the ink in the groove, so that the ink is ejected in the form of droplet to a recording medium, through the nozzle 25.

Fig. 3 is a sectional view showing in detail a structure of the heat generating resistor and a region around the resistor in a conventional ink jet print head. Fig. 4 is a plan view showing the structure shown in Fig. 3. In these figures, like or equivalent portions are designated by like reference numerals in Fig. 2, and no further description thereof will be given. In Fig. 3, reference numeral 41 designates a common electrode; 42, individual electrodes; 43, a Ta layer; 44, an Si_3N_4 layer; 45 and 46, polycrystalline silicon layers; 47, a first glass layer; 48, a second glass layer; 49, an SiO_2 layer; 50, a Si substrate; and 51 and 52, through-holes.

The SiO_2 layer 49 to be used as a heat storage layer is layered on the Si substrate 50, and then the polycrystalline silicon layer, designated by numerals 45 and 46 and to be used as a heat generating resistor, is layered on the structure. The polycrystalline silicon layer must be designed so that heat is generated only at a region thereof where bubbles are to be generated. To this end, a region of the polycrystalline silicon layer, except the heat generating region designated by numeral 45, must be reduced in its resistance. The resistance-reduced region includes the regions that are designated by numeral 46, and respectively range to the common electrode 41 and the individual electrode 42 from both sides of the polycrystalline silicon layer. To reduce the resistance of the polycrystalline silicon layers 46, impurity ions (of P or As, for example) are implanted into these layers 46.

Then, the first glass layer 47 as an interlayer insulating film is formed on the resultant. The through-holes 51 and 52 are formed in the first glass layer 47. The through-holes are for electrically connecting the resistance-reduced polycrystalline silicon layers 46 to the common electrode 41 and the individual electrode 42. Thereafter, the Si_3N_4 layer 44 as an insulating layer and the Ta layer 43 as a metal protecting layer are formed on the polycrystalline silicon layer 45. To secure a current feed to the polycrystalline silicon layer 45 to be the heat

generating resistor, an aluminum (Al) layer is patterned on the structure, to form the common electrode 41 and the individual electrode 42. The common electrode 41 and the individual electrode 42, respectively, are electrically connected to the polycrystalline silicon layers 46, through the through-holes 51 and 52, formed in the first glass layer 47. Subsequently, the second glass layer 48, the insulating layer 28, and the thick-film insulating layer 29 are formed on the structure in this order.

Fig. 5 is a diagram illustrating a conventional electrical connection of the heat generating resistor and the electrodes. As described above, each of the heat generating resistors 27 is connected at one end to the common electrode 41 and at the other end to the individual electrodes 42. Such a connection structure of the heat generating resistors is already referred to Japanese Patent Laid-Open Publication No. Hei. 5-338208, for example. The electrical connection structure, when expressed in the form of a circuit diagram, is as shown in Fig. 5. The common electrode 41 is connected to a power source, and the individual electrodes 42 are connected to drive circuits. A print signal, when applied, specifies a heat generating resistor and current is fed to the specified heat generating resistor alone.

In the connection structure referred to above, all of the heat generating resistors 27 are connected to the common electrode 41 that is connected to the power source. Accordingly, the distance from the power source varies with the position on the common electrode 41 where the electrode is connected to the heat generating resistor 27. In other words, as the distance varies, the resistance of the common electrode varies, and the voltage applied to the heat generating resistor 27 also varies in its value. As a result, the problem of voltage drop is invited. The voltage drop Vdrop is given by

$$Vdrop = I \cdot R$$

where I is current and R is resistance of the common electrode 41 ranging to the heat generating resistor 27. When the center heat generating resistor 27 located far from the power source is compared with the heat generating resistor located near the power source, a resistance of the common electrode connected to the former is larger than that of the common electrode connected to the latter. Accordingly, the voltage applied to the former is lower than that to the latter. The voltage drop Vdrop also depends on the current. Accordingly, it varies with the number of the heat generating resistors 27 driven concurrently.

When the applied voltage varies with the positions of the heat generating resistors, the jetting characteristic of each nozzle will be varied. The voltage condition required for the heat generating resistors 27 located at the ends is more severe than that for the heat generating r sistors located at the central part. As a result, the lifetime of the heat generating resistors 27 is reduced, and a variation of the characteristic resulting from jetting of ink droplet is great troublesomely.

To eliminate these drawbacks, resistance of the common electrode may be reduced by varying the film thickness, the width or the material of the common electrode. This approach suffers from some problems, however. If the thickness of the common lectrode is increased, the surface of the insulating layer layered on the electrode is irregular. Further, it is difficult to secure a good bonding of it to the channel substrate 21. To increase the width of the common electrode, it is necessary to locate the heat generating resistor more distant from the nozzle. Increase of the distance from the nozzle to the heat generating resistor leads to loss of the jetting energy. Use of material of low resistance, for example, Au, increases the cost to manufacture the print head.

The problem of the values of the voltage applied to the heat generating resistors can be solved in a manner that the drive voltage applying electrode is not connected to all of the heat generating resistors, and the electrode is folded back at each heat generating resistor. In this approach, the heat generating resistor and the folded back electrode must be put within the pixel pitch. This fact implies that the approach cannot realize a high resolution of the image. Further, the approach requires a multi-layered wiring technique. This leads to increase of defects and cost to manufacture.

The ink jet printing method has a problem that temperature also determines the amount of the ink droplet being jetted. A method to solve the temperature dependency problem is disclosed in Japanese Patent Laid-Open Publication No. Hei. 4-250057. In this method, paired pulses are used for driving the thermal ink jet head. The width of one of the paired drive pulses is varied in accordance with a temperature sensed by a thermal sensor, to thereby control the amount of ink droplet to be jetted to a desired one. The publication further describes that since the multi-nozzle head with a plural number of nozzles has a temperature distribution thereon, the width of the first pulse of the paired drive pulses is controlled individually depending on a position of the heat generating element.

SUMMARY OF THE INVENTION

It is an object of this invention to provide an ink jet printing apparatus, a driving device for driving the ink jet printing apparatus, and an ink jet printing method, which are improved in that even when the voltage applied to a plural number of heat generating resistors connected to a common electrode varies with the positions of the heat generating resistors and the number of the concurrently driven heat generating resistors, the lifetime of the heat generating resistors is not reduced, the jetting characteristics of the heat generating resistors are substantially uniform, and hence the resultant image is high in quality.

According to an aspect 1 of this present invention, there is provided an ink jet printing apparatus for ejecting ink through nozzles by the bubbles generated by

heat comprising:

a plurality of heat sources, divided into blocks, for being driven to generate heat for bubble;
a power source for supplying a drive pulse signal to the plurality of heat sources; and
a controller for controlling the width of the drive pulse signal applied from the power source to the individual heat sources so as to compensate a voltage drop based on the number of heat sources concurrently driven in a block.

According to an aspect 2 of this present invention, there is provided a driving device for an ink jet printing apparatus having:

a plurality of nozzles for ejecting ink,
fluid paths communicating with the nozzles and
heat generating resistors provided in the fluid paths, and the ink jet printing apparatus ejects ink to a recording medium through the nozzles by the bubbles generated by the heat generating resistors, comprising:

power applying means for applying, to the heat generating resistors,
an electrical drive prepulse not causing ink bubbles and
an electrical drive main pulse of a voltage higher than an ink-jetting start voltage able to jetting ink through the nozzles, and

control means

for driving the heat generating resistors in accordance with such a width of the main pulse that the ink-jetting start voltage decreases in accordance with the voltage drop of the drive voltage which is caused depending on the positions of the heat generating resistors; and
for driving the heat generating resistors in accordance with such a width of the prepulse as to correct a variation of the amount of the ink being jetted that depends on the voltage drop of the drive voltage.

According to an aspect 3 of this invention, there is provided an ink jet printing method wherein a predetermined amount of energy is applied to heat sources to generate bubbles, and ink is ejected by the generated bubbles through nozzles, comprising:

changing step of changing the width of a drive pulse signal applied from a power source to the individual heat sources in accordance with a voltage drop depending on the positions of the heat sources for compensation,
applying step of applying the compensated energy to the heat sources to generate bubbles, and
ejecting step of ejecting ink through nozzles.

In the invention of aspect 1, the heat sources are sorted into blocks in each group and driven under a control to generate heat for bubbling ink. The width of the drive pulse signal applied from the power source to the individual heat sources is controlled so as to correct a voltage drop based on the number of heat sources concurrently driven in a block. With such a construction, even if the number of the heat sources driven at the same timing is changed and the voltage drop is varied, an equal difference (margin) between an actually applied voltage and the ink-jetting start voltage is secured for all of the heat sources by varying a drive pulse condition so as to correct the variation of the voltage drop. Accordingly, the problems of the reduction of the lifetime of the heat sources and the variation of the jetting characteristics of the heat sources are successfully solved.

In the invention of aspect 2, control means drives the heat generating resistors in accordance with such a width of the main pulse that the ink-jetting start voltage decreases in accordance with the voltage drop of the drive voltage, which is caused depending on the positions of the heat generating resistors. Further, the control means drives the heat generating resistors in accordance with such a width of the prepulse as to correct a variation of the amount of the ink being jetted that depends on the voltage drop of the drive voltage. In this driving device, the voltage drop that varies depending on the positions of the heat generating resistors is corrected, and the temperature compensation is based on the positions of the heat generating resistors. Accordingly, the amount of the ink droplet being jetted is stabilized and a stable picture quality is ensured.

In the invention of aspect 3, the width of a drive pulse signal applied from a power source to the individual heat sources in accordance with a voltage drop caused depending on the positions of the heat sources, is varied for its correction. Therefore, the heat sources are able to generate ink bubbles by substantially the same energy independently of the positions of the heat sources. The uniform amounts of the ink droplets being jetted are secured and high quality pictures are printed.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing an example of a system arrangement for determining drive pulse conditions, which is used in an ink jet printing apparatus according to an embodiment of the present invention.

Figs. 2A to 2C are sectional views showing a construction of a conventional ink jet print head: Fig. 2A is a cross sectional view showing a part of the print head when it is transversely cut at a right angle to the axis of a channel groove, Fig. 2B is a sectional view taken on line B - B' in Fig. 2A, and Fig. 2C is a front view showing a part of the print head when viewed from the nozzle side.

Fig. 3 is a sectional view showing in detail a structure of the heat generating resistor and a region around the resistor in a conventional ink jet print head.

Fig. 4 is a plan view showing the structure of the heat generating resistor and its near region in the conventional ink jet print head.

Fig. 5 is a diagram illustrating a conventional electrical connection of the heat generating resistor and the electrodes.

Fig. 6 is a flowchart of a process for determining drive pulse conditions, used in the embodiment of the present invention.

Fig. 7 is a circuit diagram illustrating an electrical connection of the heat generating resistors and the electrodes, used in the embodiment of the ink jet print head of the invention.

Fig. 8 is a waveform diagram showing a waveform of a drive pulse signal used in the embodiment of the present invention.

Fig. 9 is a graph showing variations of the amount of ink droplet and an ink-jetting start voltage with respect to the prepulse width P1 and the head temperature when one heat generating resistor is driven.

Figs. 10A and 10B are graph showing voltage differences each between an actual voltage applied to the heat generating resistor, located at the end of the array of heat generating resistors, and actual voltage applied to other heat generating resistors, which were measured for different the numbers of concurrent drives.

Fig. 11 is a circuit diagram useful in explaining how the heat generating resistors are sorted into groups in the embodiment of the present invention.

Fig. 12 is a table showing the voltage correction levels determined by the positions of the heat generating resistors and the number of concurrent drives.

Fig. 13 is a graph showing a relationship between a voltage to start the jetting of ink droplet at a temperature and an amount of ink droplet being jetted when a predetermined voltage is applied.

Figs. 14A and 14B are diagram showing drive pulse conditions in temperature ranges, and the amounts of the ink droplet and the ink-jetting start voltage under the conditions.

Fig. 15 is a graph showing the results of controlling the amounts of the ink droplet being jetted and the ink-jetting start voltage in the embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 is a block diagram showing an example of a system arrangement for determining drive pulse conditions, which is used in an ink jet printing apparatus according to an embodiment of the present invention. In the figure, reference numeral 1 designates an ink jet print head; 2, a thermistor; 3, an A/D (analog to digital) converter; 4, an image signal buffer; 5, an image processing circuit; 6, a processor; 7, a correction-level determining table; 8, look-up tables; 9, a drive pulse control circuit; and 10, a power source.

The ink jet print head 1 includes a plural number of heat generating resistors, and under control of the drive pulse control circuit 9, transforms energy received from the power source 10 into heat, generates bubbles of ink by the heat, ejects ink droplets through the nozzles thereof with aid of a pressure caused by the bubbles, and prints an image on a recording medium by the ink droplets. The print head 1 may be constructed as shown in Figs. 2 through 4. One ink jet print head allows 256 nozzles to be arrayed at 24 dots/mm in resolution. In this case, the pitch Pn shown in Fig. 2C is 42 μm.

The thermistor 2 is attached to the ink jet print head 1 and used for measuring temperature of the ink jet print head 1. The A/D converter 3 converts an analog signal, which is representative of temperature measured by the thermistor 2, into a digital signal, and outputs the digital signal to the processor 6.

The image signal buffer 4 receives image signals from a host machine, and temporarily stores image signals. The image processing circuit 5 reads the image signal from the image signal buffer 4 and converts it into a bit signal for turning on and off each heat generating resistor in an operation mode, for example, a print mode, and transfers the bit signal to the drive pulse control circuit 9. The image processing circuit also extracts information representative of the number of nozzles concurrently driven in one block, which consists of a preset number of nozzles, and transfers the resultant to the processor 6.

The processor 6 receives the number of the concurrently driven nozzles in each block, the location of th block, and temperature data of the ink jet print head 1 derived from the A/D converter 3, and determines drive pulse conditions for each nozzle or block or each group of blocks. The drive pulse conditions determined are transferred to the drive pulse control circuit 9.

To determine drive pulse conditions, the correction-level determining table 7 and the look-up tables 8, for example, may be used. The correction-level determining table 7 is used for determining a correction level that is set up every voltage to be corrected on the basis f the block location and the number of the concurrently driven nozzles. The look-up tables 8 are used for obtaining a drive pulse condition every correction level in accordance with temperature of the ink jet print head 1. In an alternative to determine drive pulse conditions, formulae to produce the same results are prestored, and operated to determine the drive pulse conditions. In this case, the drive pulse conditions may directly be determined by using three factors, i.e., the number of the concurrently driven nozzles in each block, the block location, and the head temperature, for the variables of the formulae, not using th correction levels. In case where the head temperatur is negligible, only the block condition and the number of the concurrently driven nozzles may be used for determining the drive pulse conditions.

The drive pulse control circuit 9 generates a drive pulse signal on the basis of the bit signal from the image processing circuit 5 and the drive pulse condition from the processor 6, and controls the driving operation of the ink jet print head 1. As will be described later, the drive pulse signal consists of two pulses, for example. The widths of the two pulses may be controlled in accordance with the drive pulse condition.

Fig. 6 is a flowchart charting a flow of a process for determining drive pulse conditions, used in the embodiment of the present invention. An instance to be given hereunder is that temperature of the ink jet print head 1 is 22 °C to 50 °C, and a drive pulse condition is determined by using three factors, i.e., the number of the concurrently driven nozzles, the block location, and the head temperature.

Image signals, which come from a host machine, for example, a personal computer, are loaded into the image signal buffer 4 of the ink jet printing apparatus. The image signal is converted into a bit signal for turning on and off the heat generating resistor in a print mode, for example, in the image processing circuit 5. Before the printing of one line is performed, in a step S61, a voltage signal outputted from the thermistor 2, attached to the ink jet print head 1, is converted into a digital signal by the A/D converter 3, and transferred to the processor 6. In a step S62, the processor 6 receives a digital signal representative of temperature of the print head, and determines an operation based on the temperature.

If temperature of the ink jet print head 1 is 22 °C or lower, the processor determines whether or not a position at which the image signal is to be printed is within a page. If it lies at the beginning of the page, a step S64 is executed in which no printing operation is performed and a half pulse drive, for example, is performed to increase the temperature of the ink jet print head 1. A drive pulse condition used for the half pulse drive is the same as that for all of the heat generating resistors, and a single pulse of 0.8 μs in pulse width may be used. No ink bubbles are not generated by the half pulse drive, and hence no ink droplet is eject, as a matter of course. The 0.8 μs wide pulses of 6×10^4 (for about 5 seconds) are applied to all of the heat generating resistors. Thereafter, the processor returns to the step S61 where temperature of the ink jet print head 1 is measured again. The process of the half pulse drive is repeated till the head temperature exceeds 22 °C.

If the head temperature is 50 °C or higher, it is determined whether or not a position at which the image signal is to be printed is within a page. If it lies at the beginning of the page, the printing operation is stopped, and the processor returns to th step S61. The printing operation does not start until the t mperature of the ink jet print head 1 drops below 50 °C.

The branching of the process, caused by the sensed temperature of the ink jet print head 1, is applied to the start of writing one page. In case where the print position is within one page and the head temperature exceeds 22°C or lower or 50°C or higher, the drive pulse condition is determined by the following method, and the printing operation is continued.

If the temperature of the ink jet print head 1 exceeds 22°C but is lower than 50°C, a bit signal of one line is sent to the drive pulse control circuit 9. In a step S67, information representative of the number of the concurrently driven nozzles in each block is extracted, and sent to the processor 6.

In a step S68, the processor 6 determines a correction level, i.e., a look-up table 8 to be used, on the basis of the block location and the number of the concurrently driven nozzles, by using the correction-level determining table 7. In a step S69, the processor determines a drive pulse condition on the basis of the temperature of the ink jet print head 1 by using the look-up tables 8. The tasks of the steps S68 and S69 may also be carried out by using preset formulae. In one or more number of blocks at both ends or at the central part of the ink jet print head 1, there is a case where no correction is required for some initial settings. In this case, for the correction level, the correction by the table or the formulae may be omitted.

The drive pulse condition thus determined for each block is sent to the drive pulse control circuit 9. In a step S70, the drive pulse control circuit 9 generates a drive pulse signal on the basis of the bit signal of one line and the drive pulse condition, and sends it to the ink jet print head 1.

In a step S71, the processor determines whether or not the present print position lies on the final line of the image to be printed. If the image to be printed is still left, the processor returns to the step S61, and performed the process of the next line.

In the above-mentioned embodiment, the temperature range is set to be 22°C to 50°C, but another optimal temperature range may be used and set in the stage of design. While the operation is thus altered depending on temperature, the drive pulse condition may be determined by the block location, the number of the concurrently driven nozzles and the temperature of the ink jet print head 1 over the entire range of temperature.

Fig. 7 is a circuit diagram illustrating an electrical connection of the heat generating resistors and the electrodes, used in the embodiment of the ink jet print head of the invention. In the figure, reference numeral 27 designates heat generating resistors; 41, common electrodes; and 42, individual electrodes. The ink jet print head 1 is provided with 256 nozzles, for example. The first ends of the heat generating resistors corresponding to the 256 nozzles are connected to the common electrodes 41, which are for supplying a drive voltage. Th second ends of these heat generating resistors are connected to the individual electrodes 42, which are connected to a drive circuit, not shown. Current is fed to only the heat generating r sistor or resistors selected according to a print signal. In Fig. 7, serial numbers N#1 to N#256 are assigned to the nozzles in the order from left to right, respectively.

In this instance, 256 nozzles are grouped into 16 blocks. These blocks are sequentially driven. In Fig. 7, nozzles N#1 to N#16 form a block 1; nozzles N#17 to N#32, a block 2; ... ; N#240 to N#256, a block 16. The nozzles of the blocks 1 and 16 are substantially equally distanced from the power sources. When the nozzles of the blocks 2 and 15 are compared with the nozzles of the blocks 1 and 16, the distance of the former nozzles from the power sources is longer than of the latter. Accordingly, the voltage applied through the common electrodes 41 to the former nozzles more drops than to the latter.

There is a possibility that the sixteen nozzles of one block are concurrently driven. The quantity of the current flowing through the common electrode depends on the number of the nozzles, concurrently driven. Also in case where the nozzles of one block are driven, the voltage drop by the wiring resistance varies depending on the number of the concurrently driven nozzles.

Thus, the voltage drop varies depending on the locations of the nozzle blocks and the number of nozzles driven in the block. In the present invention, thermal energy is equally supplied to the heat generating resistors of all of the nozzles in a manner that the voltage drop is corrected by controlling the pulse width of the drive pulse signal. The control of the drive pulse signal will be described hereunder.

Fig. 8 is a waveform diagram showing a waveform of a drive pulse signal used in the embodiment of the present invention. The drive pulse signal, used in this instance, consists of twin pulses, as shown in Fig. 8. The first pulse, called a prepulse, is used for increasing and adjusting ink temperature around the heat generating resistor without discharging ink. The width P1 of the prepulse is selected so as not to make bubbles of ink. The second pulse, called a main pulse, is used for making ink bubbles above the heat generating resistor and causing ink to be ejected in the form of ink droplet through the nozzle. The width P3 of the main pulse is selected to be optimum for ejecting a preset amount of ink droplet. The interval P2 between the prepulse and the main pulse is used for transmitting the heat generated by the prepulse to the ink around the heat generating resistor to obtain a uniform temperature distribution. The amount of ink droplet is controlled by changing the widths P1 to P3 of the drive pulse waveform. The prepulse is not always present, and sometimes the drive pulse signal consists of only the main pulse.

Fig. 9 is a graph showing variations of the amount of ink droplet and an ink-jetting start voltage with respect to the prepulse width P1 and the head temperature when one heat generating resistor is driven. In this instance, the main pulse width P3 is 1.6 µs. In the graph, bold broken lines indicate boundaries, spaced 2 V, where the ink-jetting start voltage is changed. Thin solid lines indicate boundaries, spaced 2pl, where the amount of the ink droplet being jetted is changed.

The ink-jetting start voltage is a minimum drive voltage necessary for ejecting ink in the form of an ink droplet when the head temperature and the prepulse width are determined. Ink decreases its viscosity when temperature rises, so that it is possible to eject the ink droplet under the condition of low voltage. In other words, the drive voltage required for ejecting the ink droplet is lower, the higher the head temperature is. Accordingly, when the prepulse width is increased, ink temperature rises, and consequently the drive voltage required for ejecting the ink droplet is low. In the graph, the equal values of ink-jetting start voltage are connected by lines, and any voltage contained in the regions located on the left side of and under the lines cannot eject the ink droplet.

To plot variations of the ink droplets in the graph, the ink droplets were ejected with the drive voltage of 37 V. As the prepulse width P1 is longer, temperature of ink around the heat generating resistor more rises, ink bubbles generated above the heat generating resistor more grow, and hence the amount of ink droplet being jetted is larger. Also when the head temperature is high, the bubbles grow, and the viscosity of the ink around the heat generating resistor decreases. In this state, the ejecting of the ink droplet is easier. This results in increase of the amount of the ink droplet. Thus, the amount of the ink droplet varies depending on both the prepulse width P1 and the head temperature. The fact implies that a variation of the amount of the ink droplet when temperature varies can be controlled by varying the prepulse width P1.

In the graph, a bold line indicates a steplike variation of the prepulse width P1 so as to keep the amount of the ink droplet at constant values. The amount of the ink droplet also depends on the main pulse width P3. As seen, in the region above 46°C the prepulse width P1 is 0, and therefore the amount of the ink droplet cannot b controlled by using the prepulse width P1. In the region where the prepulse width P1 is 0, however, the amount of the ink droplet can be controlled so as to be kept constant until a further higher temperature is reached, by varying the main pulse width P3, for example, to 1.4 µs.

In this instance, the total of the widths P1, P2 and P3 is set at a fixed value: $P + P2 + P3 = 6.5\ \mu s$. Accordingly, if the widths P1 and P3 are changed, the interval P2 also is changed. In other words, a variation of the amount of the ink droplet, which is caused by changing the widths P1 and P3, also results from a change of the interval.

In the example indicated by the bold line in Fig. 9, a target value (center value) of the amount of the ink droplet, which corresponds to the resolution of 24 dots/mm, was set at 19 pl, and the prepulse width P1 and the main pulse width P3 were varied so that the amount of the ink droplet fell within ± 1.4 pl. The control range of the amount of the ink droplet may be selected to such an extent as to have a negligible density difference in an image (in this instance, it is 2.8 pl).

In the instance of Fig. 9, one heat generating resistor is driven. As described referring to Fig. 7, in this embodiment, the number of concurrently driven nozzles

(the number of concurrent drives) is 16 at maximum. Where the ejecting of the ink droplet is repeated at a fixed frequency, the printing speed is high as the number of concurrent drives is larger. In this case, the current flowing to the common electrodes increases, and hence the voltage drop increases. The number of concurrent drives is within 16 and depends on a kind of the image signal. When an image of high image density, for example, a solid image, is printed, the number of concurrent drives is high. When a character image is printed, it is low. Thus, the voltage drop depends on the number of concurrent drives , viz., a kind of the image signal.

Fig. 10 is a graph showing voltage differences each between an actual voltage applied to the heat generating resistor, located at the end of the array of heat generating resistors, and actual voltage applied to other heat generating resistors, which were measured for different the numbers of concurrent drives. In this instance, the drive frequency was fixed at 12 kHz, and 37 V was applied to the common electrodes. In Fig. 10, there are plotted potential differences each between the heat generating resistor associated with the nozzle N#1, located at the end of the nozzle array, and each of the heat generating resistors associated with the nozzles N#32, N#64, N#96 and N#128, which were measured for different numbers of concurrent drives in the blocks 1, 2, 4 and 8.

As seen from the graph, where the number of concurrent drives is small, potential differences between the heat generating resistors located at different positions are small. As the number of concurrent drives increases, the current flowing into the heat generating resistors increases, and the voltage drops are large. As a consequence, the differences between the heat generating resistors located at different positions are large.

In this embodiment, the maximum number of the concurrent drives is 16, and a voltage difference between the center heat generating resistor (associated with the nozzle N#128) which receives the voltage most dropped, and the heat generating resistor (associated with the nozzle N#1), is 2.0 V at maximum. The graph of Fig. 10 graphically illustrates the voltage differences of the heat generating resistors associated with the nozzles N#1 to N#128. As shown in Fig. 7, the array of the heat generating resistors receives at both ends thereof the drive voltage from the different power sources. The remaining heat generating resistors, associated with the nozzles N#129 to N#256, are symmetrically arrayed as those mentioned above. Then, the voltage drops are caused in a similar way.

It is empirically known that if a difference (margin) between an ink-jetting start voltage and a voltage actually applied to the heat generating resistors is 0.5 V or larger, the differences of the amounts and the speeds of ink droplets b ing ejected, and variations of the amounts of ink droplet caused by the burning of the surfaces of the heat generating resistors repetitively driven, are observed on the heat generating resistors. The difference of the ink droplet amounts between the heat generating resistors appears as an irregularity of optical density in a monochromatic image. In a color image, the droplet amount difference makes the color balances differ with the locations on the image.

The maximum voltage difference between the heat generating resistors located at different positions is 2.0 V. To put the voltage difference between the heat generating resistors, located at different positions, within 0.5 V, the heat generating resistors of 256 being sorted into four groups in accordance with the voltage difference will do. As seen from Fig. 10A, the voltage drop, which is a voltage difference between the heat generating resistor positioned at the end of the resistor array and another heat generating resistor located at another position on the resistor array, proportionally increases from one end of the resistor array to the center thereof. The heat generating resistors may be sorted into four groups in a manner that 32 heat generating resistors, counted from each end of the resistor array, totally 64 heat generating resistors, are sorted into one group.

Fig. 11 is a circuit diagram useful in explaining how the heat generating resistors are sorted into groups in the embodiment of the present invention. As seen, a group 1 consists of a total of 64 heat generating resistors, 32 heat generating resistors associated with the nozzles N#1 to N#32 and 32 heat generating resistors associated with the nozzles N#225 to N#256. Similarly, a group 4 consists of 64 heat generating resistors associated with the nozzles N#97 to N#160. In the group 1, between the heat generating resistors of the nozzles N#1 and N#32, which are most apart from each other, the applied voltage difference resulting from the voltage drop is within 0.5 V. A similar correction is applicable to the group. In other groups, the difference between the voltages applied to the heat generating resistors is within 0.5 V.

The correction is made in the steps of 0.5 V. Then, the voltage necessary for the correction is divided into four levels, levels 0 to 3 as shown in Fig. 10B, in accordance with the voltage difference. The correction levels are also shown in Fig. 10A. The correction level 0 indicates that there is no correction for the voltage drop. The correction is made for the voltage difference with respect to the voltage in the group 1, and hence the correction level of the group 1 is always 0.

Fig. 12 is a table showing the voltage correction levels determined by the positions of the heat generating resistors and the number of concurrent drives. In the graph of Fig. 10A, the most dropped voltage appears at the heat generating resistor of the nozzle N#64 in the group 2. The same appears at the heat generating resistors of the nozzles N#96 and N#128 in the groups 3 and 4. When the number of concurrent drives is varied from 1 to 16, the maximum voltage drop in each group and hence a necessary voltage correction level can be seen from the graph of Fig. 10A. This process can be tabulated as shown in Fig. 12. In th table, figures, located under the number of concurrently driven heat

generating resistors 1 to 16, indicate the correction levels. In the group 3, for example, the correction level is 0 in the range of 1 to 5 of the number of concurrent drives, and hence no voltage correction is required. In the range of 6 to 10, the maximum voltage difference is 0.5 V. Accordingly, the voltage correction by the correction level 1 is required. In the range of 11 to 16, the maximum voltage difference exceeds 1 V. Accordingly, the voltage correction by the correction level 2 is required. The table of Fig. 12 may be used for the correction-level determining table 7 in Fig. 1.

Fig. 13 is a graph showing a relationship between a voltage to start the jetting of ink droplet at a temperature and an amount of ink droplet being jetted when a predetermined voltage is applied. As already stated, the actually applied voltage to start the jetting of the ink droplet at a temperature is called an ink-jetting start voltage. As shown also in Fig. 9, the ink-jetting start voltage varies depending on temperature of the print head and the pulse width of the prepulse. In Fig. 13, solid lines indicate relationships between the ink-jetting start voltage when $P1 + P2 + P3 = 6.5\ \mu s$, the pulse width P3 of the main pulse was fixed at 1.4 µs, 1.6 µs, 1.8 µs and 2.0 µs, and the pulse width P1 of the prepulse was varied from 0 to 1.0 µs, and the amount of the ink droplet being jetted when the drive voltage applied was 37 V. Dotted lines indicate relationships between the ink-jetting start voltage when the prepulse width P1 was fixed at 0 µs and 1.0 µs and the main pulse width P3 was varied from 1.4 µs to 2.0 µs, and the amount of the ink droplet being jetted when the drive voltage applied was 37 V. A range of 19 ± 1.4 pl is hatched for showing an example of an optimum control range of the amount of ink droplet.

As seen from the graph, when the prepulse width P1 is increased, the amount of the ink droplet being jetted increases and the ink-jetting start voltage decreases. Further, it is seen that when the main pulse width P3 is long, the amount of the ink droplet being jetted is large and the ink-jetting start voltage is low.

Thus, a drive pulse condition where the amounts of the ink droplet being jetted are substantially equal to each other but the ink-jetting start voltages are different from each other, exists. From this, it is seen that the main pulse width P3 dominantly determines the ink-jetting start voltage, and the prepulse width P1 dominantly determines the amount of the ink droplet being jetted. Accordingly, only one of the ink-jetting start voltage and the amount of the ink droplet being jetted may be varied by properly combining those pulse widths.

As seen from the graph shown in Fig. 10A and the table shown in Fig. 9, when the ink-jetting start voltage is decreased to the amount of the applied voltage difference, given in the steps of 0.5 V, which is determined by the positions (group) of the heat generating resistors and the number of concurrent drives, the difference between the actually applied voltage and the voltage for jetting the ink droplet may be kept substantially at a fixed value (within 0.5 V) for the heat generating resistors, independently of the kind of image (the number of concurrent drives) and the positions of the heat generating resistors.

As described above, temperature also greatly affects the amount of the ink droplet being jetted. In the present embodiment, the print head can be controlled so as to jet a preset amount of ink droplet independently of temperature in a manner that temperature of the ink jet print head is sensed by the thermistor attached to the print head, and a signal representative of the sensed temperature is additionally used to change the drive pulse condition. A method for keeping the amount of the ink droplet at a fixed value in a manner that the drive pulse condition is changed also by temperature, while the voltage difference, which is determined by the positions of the heat generating resistors and the number f concurrent drives, is corrected by changing the drive condition, will be described.

Fig. 14 is a diagram showing drive pulse conditions in temperature ranges, and the amounts of the ink droplet and the ink-jetting start voltage under the conditions. The relationship, as shown in Fig. 13, between the drive pulse condition, and the amount of the ink droplet being jetted and the ink-jetting start voltage is obtained every temperature within a temperature range within which the ink jet print head will be used, thereby to find a drive pulse condition where the amount of the ink droplet being jetted is invariable at every temperature, but the ink-jetting start voltage is different to the amount of the voltage drop. The drive pulse conditions of the correction level 0 thus obtained are tabulated in Fig. 14A, and the drive pulse conditions of the correction level 3 of which the ink-jetting start voltage is different by 2 V from that of the correction level 0, are tabulated in Fig. 14B. The drive pulse condition tables as shown in Fig. 14 may be used for the look-up tables 8 in Fig. 1.

As the temperature step used to sense temperature and to change the drive pulse condition is smaller, the control of the amount of the ink droplet being jetted is finer. As the variation of the pulse width is smaller, the amount of the ink droplet being jetted is kept more constant. Where the temperature step is small and the pulse width variation is small, the requirements for the sensing accuracy of the thermistor and the pulse width accuracy are more strict, resulting in increase of the cost to manufacture. In the present embodiment, as shown in Fig. 14, the temperature step is 4°C, and the minimum variation of the pulse width is 0.1 µs. The prepulse width P1 for causing ink bubbles is within 1 µs, although it varies depending on the drive voltag and temperature.

In the instance shown in Fig. 14, proper amounts of ink droplets are obtained in the temperature range of 22°C or lower. If the print is made in this temperatur range, the amount of ink droplet is insufficient. Accordingly, the printed image will suffer from an insufficient density. To avoid this, another printing method may be used. For example, the half-pulse drive to increase only the head temperature is performed as shown in the

flowchart of Fig. 6. After the print head is heated to a satisfactory temperature, the printing operation is started.

Fig. 15 is a graph showing the results of controlling the amounts of the ink droplet being jetted and the ink-jetting start voltage in the embodiment of the present invention. Variations of the amounts of the ink droplet being jetted and the ink-jetting start voltage when temperature of the ink jet print head is varied from 10°C to 50°C are illustrated in Fig. 15. Bold lines indicate the results of the control, carried out by using the table of the correction level 0 shown in Fig. 14A, and thin lines indicate the results of the control, carried out by using the look-up tables 8 as the table of the correction level 3 shown in Fig. 14B, which is for correcting the voltage difference of 2 V. Solid lines indicate variations of the amount of the ink droplet being jetted, and dotted lines indicate variations of the ink-jetting start voltage.

In low temperatures below 22°C, the maximum value 1.0 µs or 0.9 µs of the prepulse width P1 is applied, from the table shown in Fig. 14. In this temperature range, the target value of the amount of the ink droplet being jetted is out of a range of 19 pl ± 1.4 pl. Accordingly, the half pulse drive is carried out to heat the ink jet print head up to 22 °C. In the graph, the temperature range where the half pulse drive is carried out is hatched. As the result of the half pulse drive, the amount of the ink droplet being jetted falls within the control range, and the printing operation starts.

After the temperature of the ink jet print head exceeds 22°C, the half pulse drive is stopped and the amount of the ink droplet being jetted is controlled through only the changing of the drive pulse condition. The drive pulse condition is changed every step of 4 °C, and the amount of the ink droplet being jetted is kept within the control range.

Thus, in the present invention, even in the cases of the correction levels 0 and 3, the amount of the ink droplet being jetted may be within the range of 19 pl ± 1.4 pl in the temperature range up to 50 °C. When the table of the correction level 3 shown in Fig. 14B is used, the ink-jetting start voltage was lower by about 2 V of the voltage drop than when the table of the correction level 3 shown in Fig. 14A is used. Similar results were obtained for the tables of the correction levels 2 and 3. The amount of the ink droplet being jetted could be controlled to be within a proper amount of ink droplet at large. Accordingly, the picture quality improvement was secured.

As seen from the foregoing description, in the present invention, the condition of the drive pulse signal applied to the heat generating resistors is changed by the positions of the heat generating resistors and the number of concurrent drives. Accordingly, the invention can suppress a variation of the amounts of the ink droplet being jetted by the heat generating resistors, caused by the voltage margin. Further, the invention can minimize a variation of the amount of the ink droplet being jetted, caused by temperature, since the drive pulse condition is set up by additionally using the temperature of the ink jet print head, sensed by the thermistor.

Claims

1. An ink jet printing apparatus for ejecting ink through nozzles by the bubbles generated by heat comprising:

   a plurality of heat sources, divided into blocks, for being driven to generate heat for bubble;
   a power source for supplying a drive pulse signal to said plurality of heat sources; and
   a controller for controlling the width of the drive pulse signal applied from said power source to said individual heat sources so as to Compensate a voltage drop based on said number of heat sources concurrently driven in a block.

2. The ink jet printing apparatus of claim 1, further comprising:

   a common electrode for connecting first terminals of said heat sources to said power source, wherein
   the width of the drive pulse signal applied from said power source to said individual heat sources are controlled in accordance with the positions of said heat sources.

3. The ink jet printing apparatus of claim 2, wherein
   the drive pulse signal includes a prepulse not causing bubbles of ink and a main pulse causing ink bubbles, and
   the pulse widths of the prepulse and the main pulse are varied.

4. The ink jet printing apparatus of claim 2, wherein
   said controller determines whether the voltage drop is compensated every block, on the basis of the location of each block and the number of said concurrently driven heat sources in the block.

5. The ink jet printing apparatus of claim 3, wherein
   the width of the main pulse is varied in a range of 1.4 to 2.0 µs.

6. The ink jet printing apparatus of claim 4, wherein
   the applied voltage difference is within 0.5 V.

7. A driving device for an ink jet printing apparatus having:

   a plurality of nozzles for ejecting ink,
   fluid paths communicating with said nozzles and
   heat generating resistors provided in said fluid paths, and the ink jet printing apparatus ejects ink to a recording medium through the nozzles

by the bubbles generated by said heat generating resistors, comprising:

power applying means for applying, to said heat generating resistors,
an electrical drive prepulse not causing ink bubbles and
an electrical drive main pulse of a voltage higher than an ink-jetting start voltage able to jetting ink through said nozzles, and

control means

for driving said heat generating resistors in accordance with such a width of the main pulse that the ink-jetting start voltage decreases in accordance with the voltage drop of the drive voltage which is caused depending on the positions of said heat generating resistors; and
for driving said heat generating resistors in accordance with such a width of the prepulse as to correct a variation of the amount of the ink being jetted that depends on the voltage drop of the drive voltage.

8. The driving device for an ink jet printing apparatus of claim 7, further comprising:

a common electrode for connecting first terminals of said heat generating resistors to said power applying means, wherein
the width of the drive pulse signal applied from said power applying means to said individual heat generating resistors are controlled in accordance with the positions of said heat generating resistors.

9. The ink jet printing apparatus of claim 8, wherein said controller determines whether the voltage drop is compensated every block, on the basis of the location of each block and the number of said concurrently driven heat sources in the block.

10. The ink jet printing apparatus of claim 9, wherein the width of the main pulse is varied in a range of 1.4 to 2.0 μs.

11. The ink jet printing apparatus of claim 10, wherein the applied voltage difference is within 0.5 V.

12. An ink jet printing method wherein a predetermined amount of energy is applied to heat sources to generate bubbles, and ink is ejected by the generated bubbles through nozzles, comprising:

changing step of changing the width of a drive pulse signal applied from a power source to said individual heat sources in accordance with a voltage drop depending on the positions of said heat sources for compensation,
applying step of applying the compensated energy to said heat sources to generate bubbles, and
ejecting step of ejecting ink through nozzles.

13. The ink jet printing method of claim 12, wherein said changing step further comprises:

the step of detecting the number of said heat sources concurrently driven in one of a preset number of blocks, and
the step of judging whether the voltage drop is corrected for each block on the basis of the number of said concurrently drive heat sources detected and the location of the block.

14. The ink jet printing method of claim 12, further comprising:

the step of detecting temperature around said heat sources, and
the step of varying the width of the pulse signal applied from said power source to said heat sources in accordance with the detected temperature.

FIG. 1

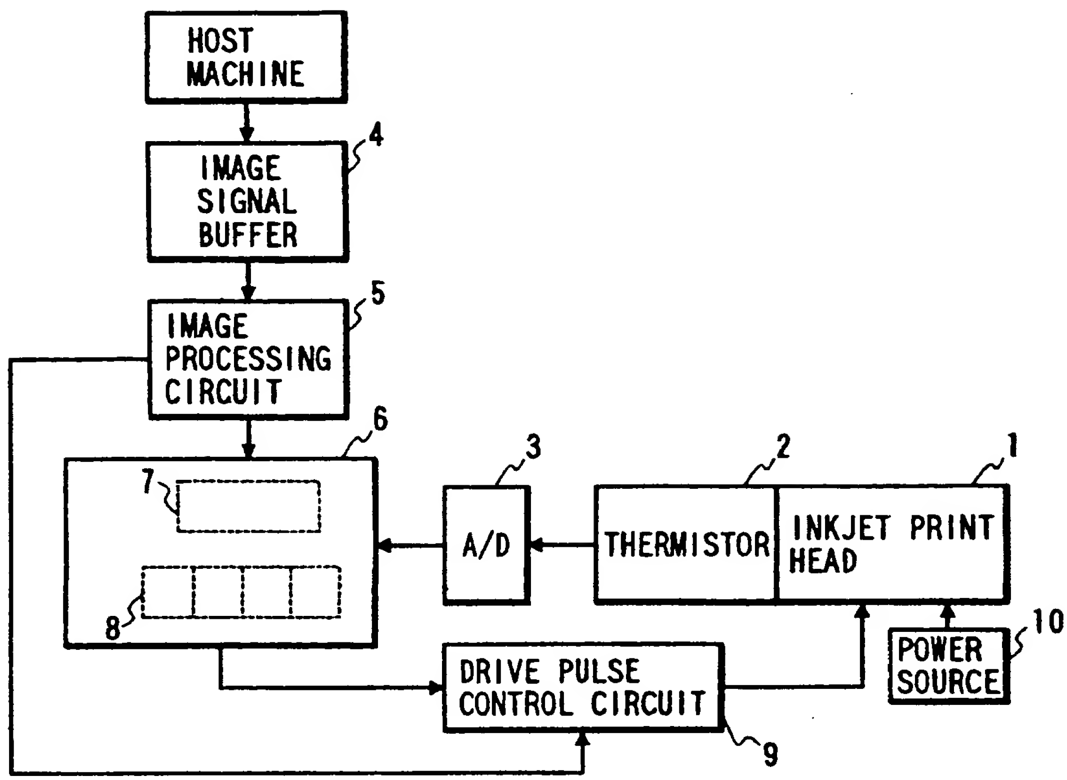
HOST MACHINE
4
IMAGE SIGNAL BUFFER
5
IMAGE PROCESSING CIRCUIT
6
7
8
3
A/D
2
THERMISTOR
1
INKJET PRINT HEAD
10
POWER SOURCE
DRIVE PULSE CONTROL CIRCUIT
9

FIG. 3

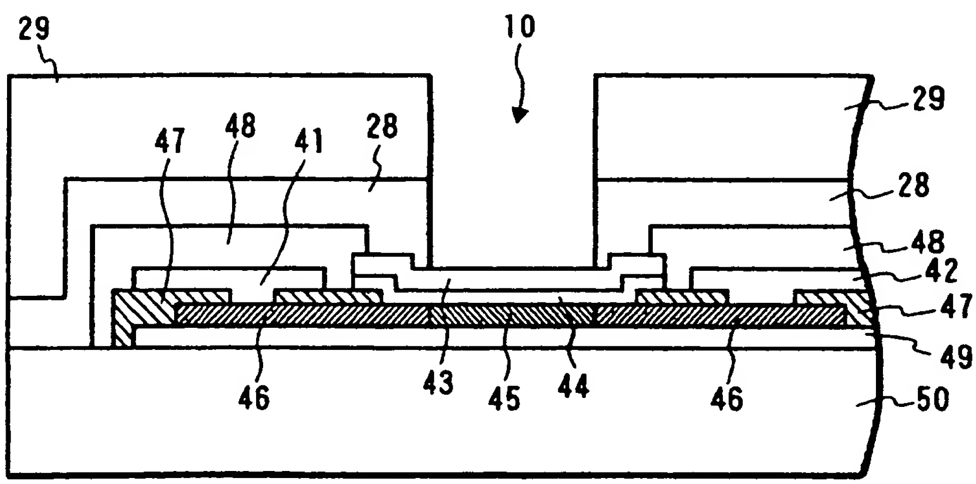
29
10
29
47
48
41
28
28
48
42
47
49
46
43
45
44
46
50

FIG. 2A

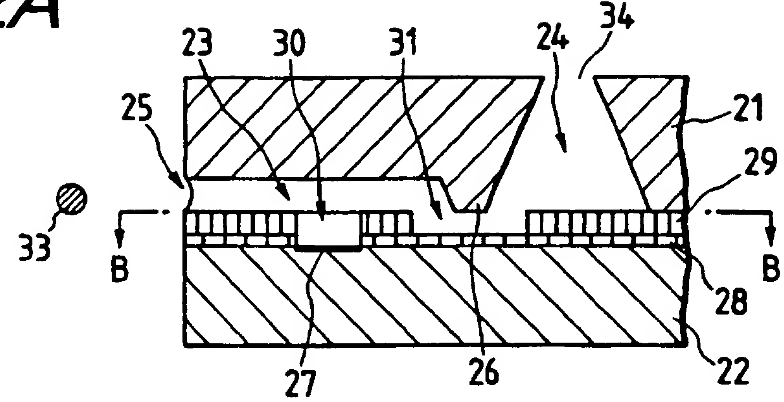

FIG. 2B

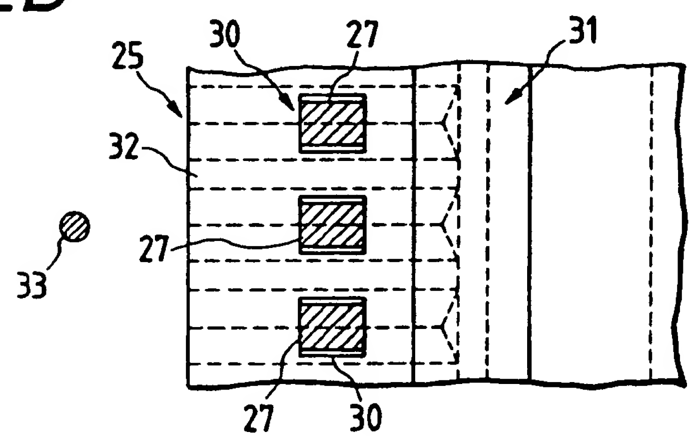

FIG. 2C

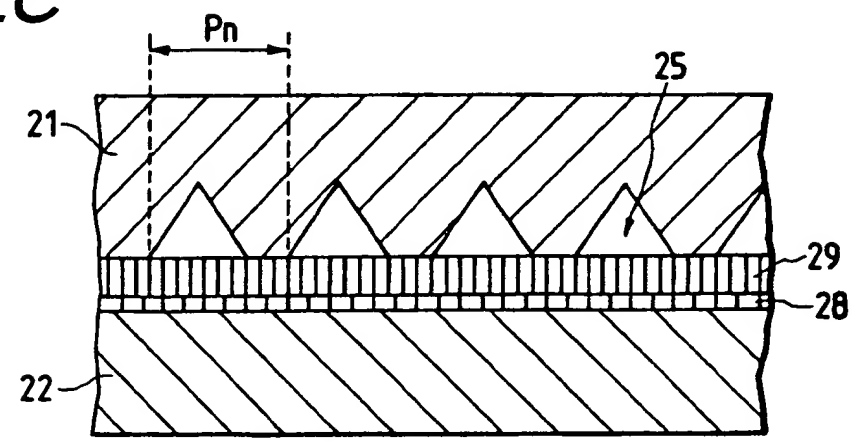

FIG. 4

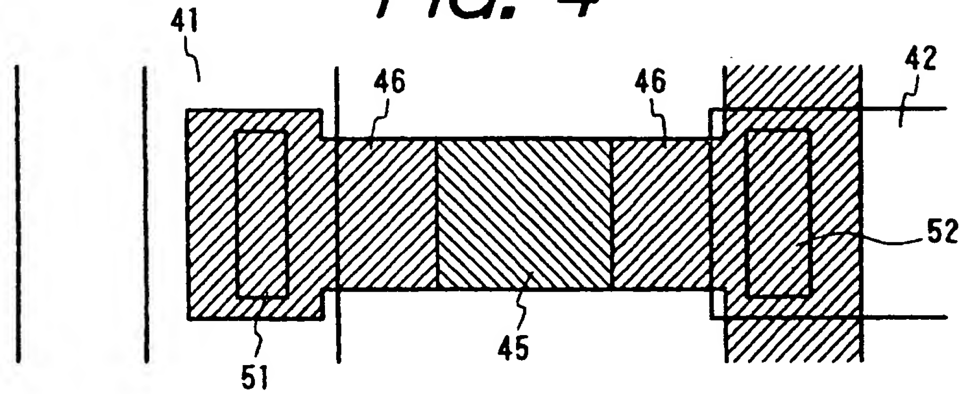

FIG. 5

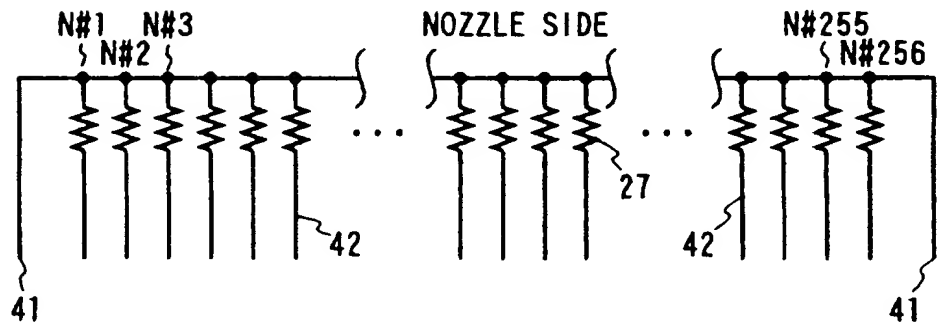

FIG. 7

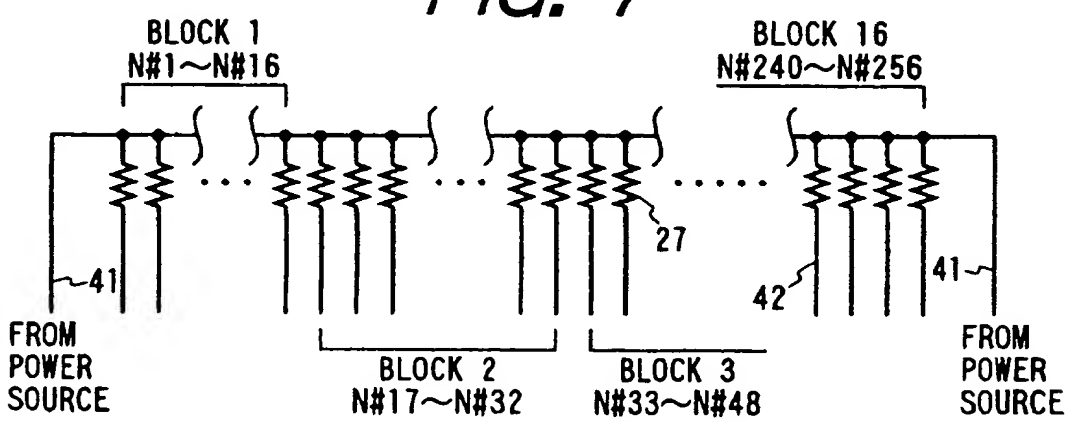

FIG. 6

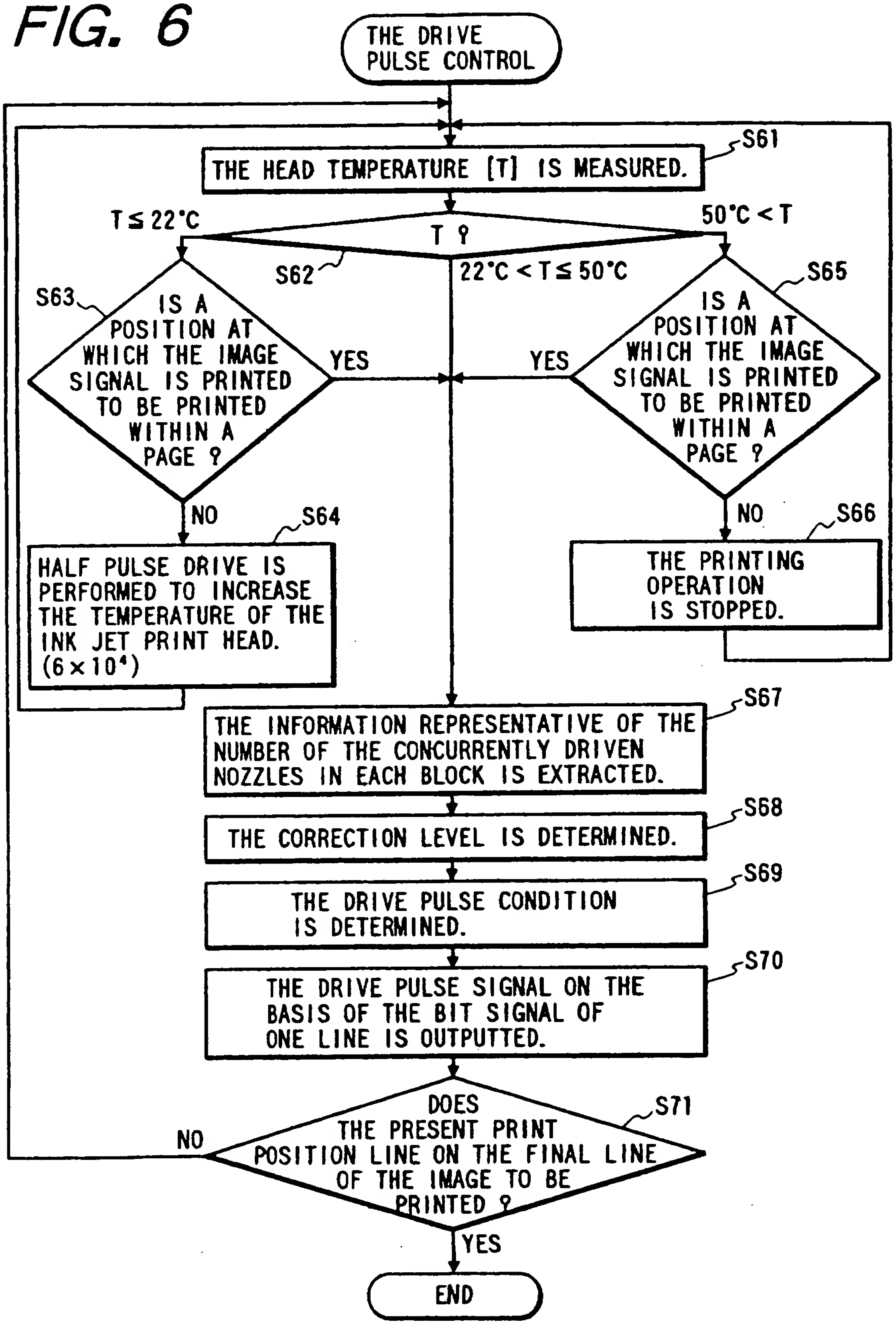
THE DRIVE PULSE CONTROL
THE HEAD TEMPERATURE [T] IS MEASURED.
S61
T ≤ 22°C
T ?
50°C < T
S62
22°C < T ≤ 50°C
S63
IS A POSITION AT WHICH THE IMAGE SIGNAL IS PRINTED TO BE PRINTED WITHIN A PAGE ?
YES
NO
S64
HALF PULSE DRIVE IS PERFORMED TO INCREASE THE TEMPERATURE OF THE INK JET PRINT HEAD. (6×10⁴)
S65
IS A POSITION AT WHICH THE IMAGE SIGNAL IS PRINTED TO BE PRINTED WITHIN A PAGE ?
YES
NO
S66
THE PRINTING OPERATION IS STOPPED.
S67
THE INFORMATION REPRESENTATIVE OF THE NUMBER OF THE CONCURRENTLY DRIVEN NOZZLES IN EACH BLOCK IS EXTRACTED.
S68
THE CORRECTION LEVEL IS DETERMINED.
S69
THE DRIVE PULSE CONDITION IS DETERMINED.
S70
THE DRIVE PULSE SIGNAL ON THE BASIS OF THE BIT SIGNAL OF ONE LINE IS OUTPUTTED.
S71
DOES THE PRESENT PRINT POSITION LINE ON THE FINAL LINE OF THE IMAGE TO BE PRINTED ?
NO
YES
END

FIG. 8

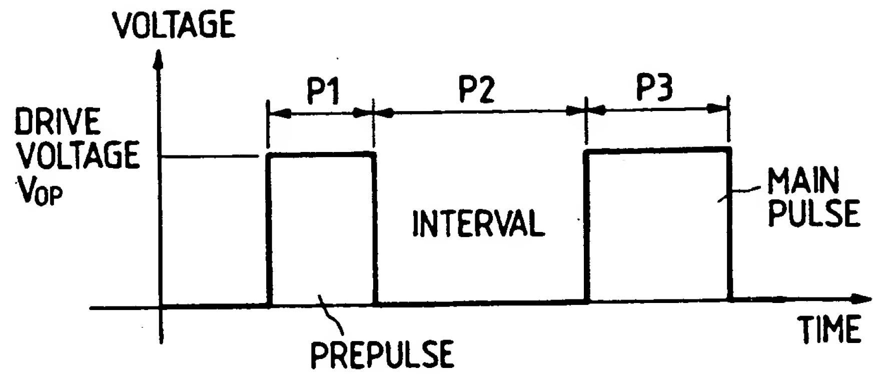
VOLTAGE
DRIVE VOLTAGE Vop
P1
P2
P3
INTERVAL
MAIN PULSE
PREPULSE
TIME

FIG. 9

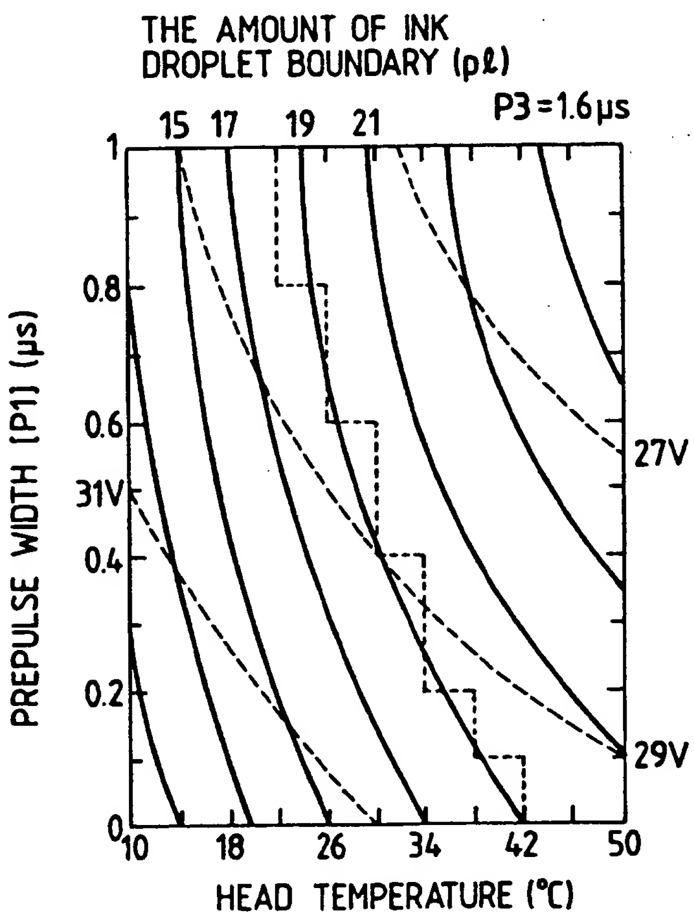
THE AMOUNT OF INK DROPLET BOUNDARY (pℓ)
15
17
19
21
P3=1.6μs
PREPULSE WIDTH (P1) (μs)
1
0.8
0.6
31V
0.4
0.2
0
27V
29V
10
18
26
34
42
50
HEAD TEMPERATURE (°C)

FIG. 10A

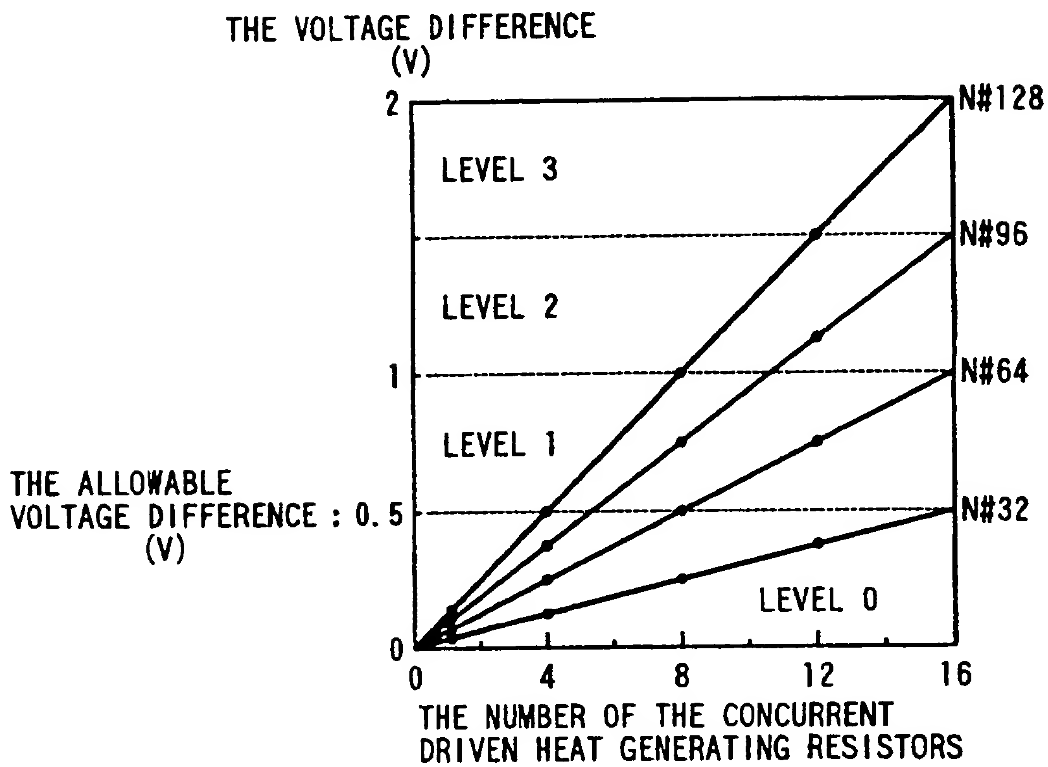

FIG. 10B

THE VOLTAGE DIFFERENCE (V)	THE CORRECTION LEVEL OF THE VOLTAGE DIFFERENCE
0~0.5	0
0.5~1.0	1
1.0~1.5	2
1.5~2.0	3

FIG. 11

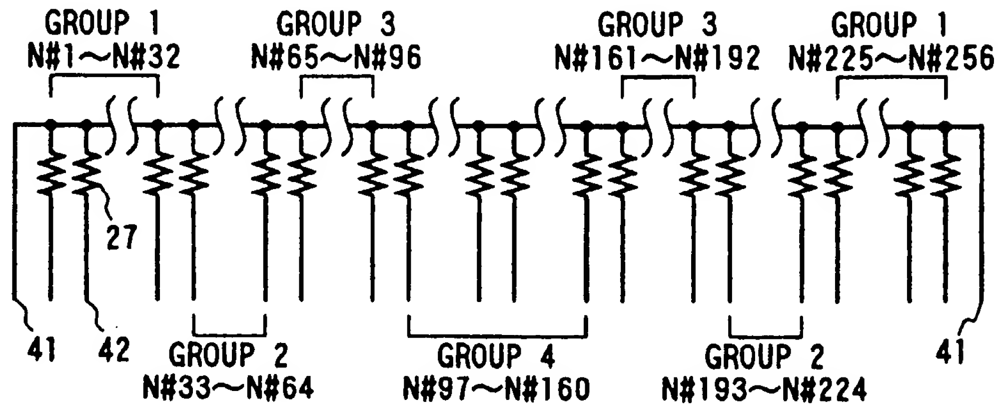

FIG. 12

THE GROUPS OF HEAT GENERATING RESISTORS	THE NOZZLE NO. ASSOCIATED WITH HEAT GENERATING RESISTORS	THE NUMBER OF CONCURRENT DRIVER HEAT GENERATING RESISTORS															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1～32, 225～256	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	33～64, 193～224	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
3	65～96, 161～192	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2
4	97～160	0	0	0	1	1	1	1	2	2	2	2	3	3	3	3	3

FIG. 13

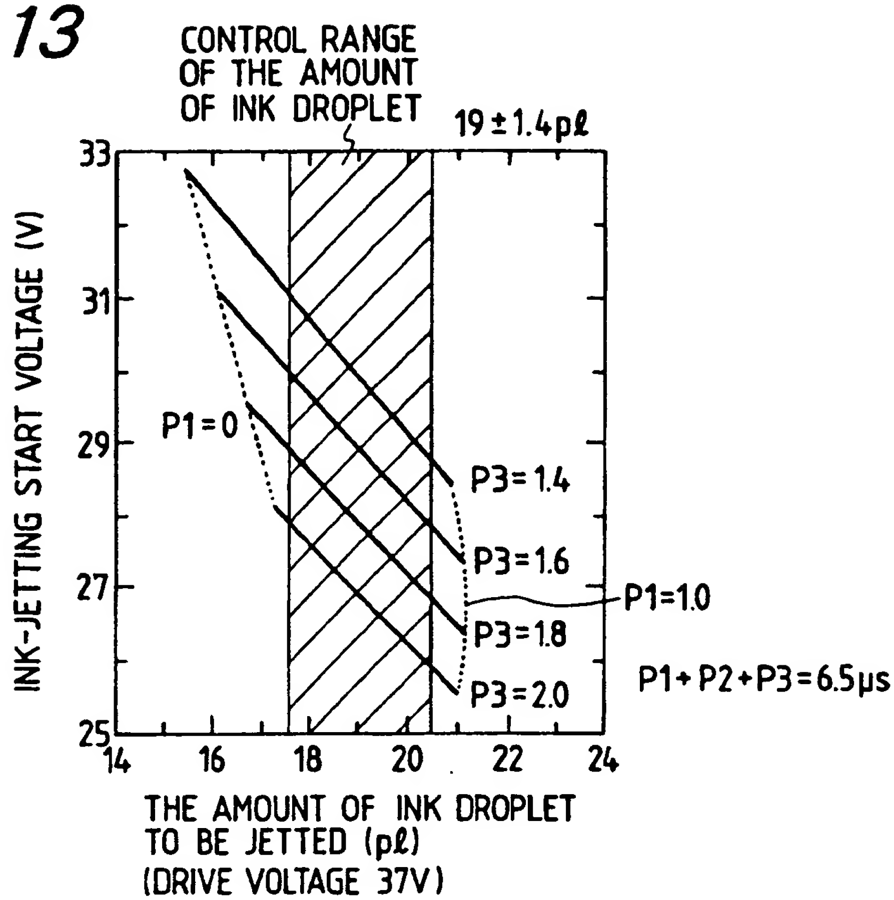
CONTROL RANGE
OF THE AMOUNT
OF INK DROPLET
19 ± 1.4pℓ
INK-JETTING START VOLTAGE (V)
33
31
29
27
25
P1=0
P3=1.4
P3=1.6
P3=1.8
P3=2.0
P1=1.0
P1+P2+P3=6.5μs
14
16
18
20
22
24
THE AMOUNT OF INK DROPLET
TO BE JETTED (pℓ)
(DRIVE VOLTAGE 37V)

FIG. 15

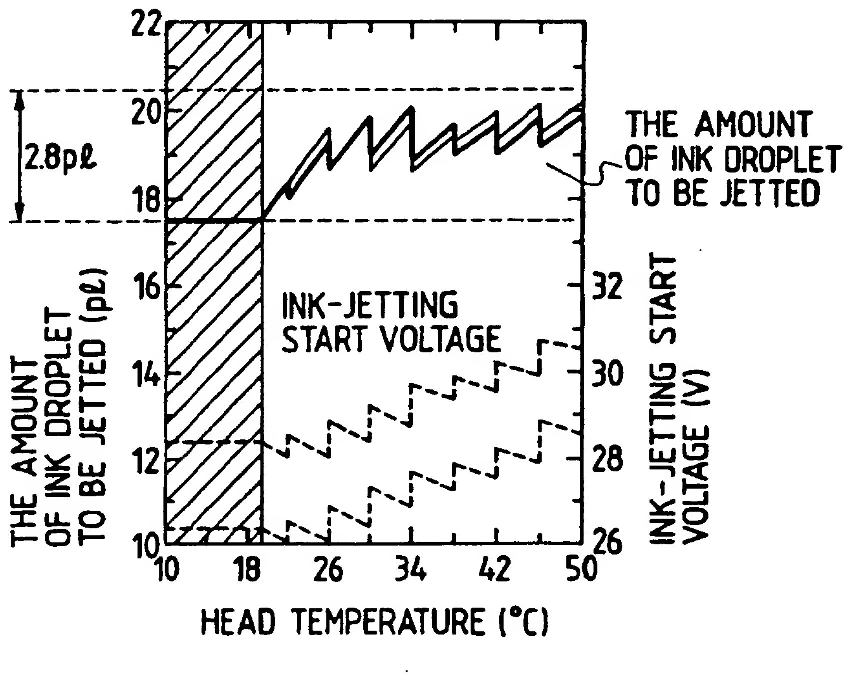
22
20
18
16
14
12
10
2.8pℓ
THE AMOUNT
OF INK DROPLET
TO BE JETTED
INK-JETTING
START VOLTAGE
THE AMOUNT
OF INK DROPLET
TO BE JETTED (pℓ)
32
30
28
26
INK-JETTING START
VOLTAGE (V)
10
18
26
34
42
50
HEAD TEMPERATURE (°C)

FIG. 14A

TEMPERATURE RANGE (°C)	PULSE CONDITION (μs)			THE AMOUNT OF THE INK DROPLET (pl)	THE INK-JETTING START VOLTAGE (V)
	P1	P2	P3		
~14	1.0	3.9	1.6		
14~18	1.0	3.9	1.6	15.1	29.0
18~22	1.0	3.9	1.6	16.8	28.5
22~26	0.8	4.1	1.6	17.9	28.5
26~30	0.6	4.3	1.6	18.6	28.7
30~34	0.4	4.6	1.6	18.9	29.0
34~38	0.2	4.7	1.6	18.7	29.6
38~42	0.1	4.8	1.6	19.0	29.7
42~46	0.0	4.9	1.6	19.0	30.0
46~50	0.0	5.1	1.5	19.3	30.7
50~	0.0	5.1	1.5	19.9	30.5

FIG. 14B

TEMPERATURE RANGE (°C)	PULSE CONDITION (μs)			THE AMOUNT OF THE INK DROPLET (pl)	Δ(THE AMOUNT OF THE INK DROPLET) (pl)	THE INK-JETTING START VOLTAGE (V)	Δ(THE INK-JETTING START VOLTAGE) (V)
	P1	P2	P3				
~14	0.9	3.5	2.1				
14~18	0.9	3.5	2.1	14.9	0.2	27.0	2.0
18~22	0.9	3.5	2.1	16.4	0.4	26.6	1.9
22~26	0.7	3.5	2.0	18.3	0.4	26.6	2.0
26~30	0.5	4.0	2.0	18.7	0.1	26.8	1.9
30~34	0.5	4.3	2.0	18.6	0.3	27.1	1.9
34~38	0.2	4.5	2.0	18.5	0.2	27.6	2.0
38~42	0.0	4.6	2.0	19.2	0.2	27.8	1.9
42~46	0.0	4.7	1.9	19.4	0.4	28.1	1.9
46~50	0.0	4.8	1.8	19.6	0.3	28.8	1.9
50~	0.0	4.8	1.8	20.2	0.3	28.5	2.0